Results of the ESSC-ESF study on

Future of International Collaboration in Space Science

Contents

Foreword

From the beginning of the Space Age in 1957 when the first Sputnik was launched, the need to consider international collaboration in the exploration and exploitation of space was recognised. While the initial motivation was mainly politically driven in view of the "cold war" situation that prevailed at the time, the strong world tradition of international collaboration in fundamental sciences quickly made itself felt. Thus many of the world's key space science missions after 1960 were collaborative in nature.

With the passage of time and the increasing maturity of the subject, the motivations for engaging in collaborative endeavours in space and the mechanisms for their realisation became more complex. However the imperatives to advance a broad and growing range of science disciplines coupled with the high cost of access to, and operation in, space strengthened the will of those involved – both space agencies and practicing scientists, to engage in collaborative programmes.

The world space science community now finds itself at a crossroads. Access to, and exploitation of, space is no longer purely politically driven. Thus in the USA in 1999 – the volume of commercial space activity overtook for the first time that of government supported programmes. In the new environment, science must continue to justify its vital importance as a cultural activity of the first rank and in developed nations this aspect has indeed long been recognised. The community can also point to its seminal role in aspects of space exploitation ranging from telecommunication and navigation to the study of Earth climate change. In addition, the space sciences have demonstrated a substantial public appeal and an outstanding ability to motivate young people to take up careers in the natural and engineering sciences.

Recognising the importance of international collaboration, the European Space Science Committee (ESSC) of the European Science Foundation (ESF) and the Space Studies Board (SSB) of the US National Research Council (NRC) published in 1998 a joint study on US-European Collaboration in Space Science ([Ref. App.4-1]). This work examined the history of past joint work and stressed the importance of continued future joint activities. More recently this study was extended to include the role of Japan's space scientists in collaborative activities ([Ref. App.4-2]).

While these studies have initially involved the USA and Europe and later Japan, the importance of scientific collaboration among all the world's spacefaring nations has been strikingly emphasised as a result. The present study seeks to (i) broaden the base of international collaboration; (ii) identify fruitful areas for such collaboration, such as large astronomical missions and solar system studies involving multiple spacecraft; and (iii) propose a coordinating body involving the major world space agencies which could address collaboration on large missions and coordination of the more focused smaller scale activities in space through the harmonisation of their programmes.

This short study was undertaken by the ESSC at the request of the European Space Agency (ESA). It has benefited greatly from the participation of individuals nominated by the SSB and by the presence of an observer from the Japanese Space Research Committee. In a time of great opportunity and popular support for the advancement of space science, it is our hope that this work will help promote more effective international collaboration and a more cost-effective approach to the realisation of our scientific goals.

John Leonard Culhane
Chairman ESSC-ESF

Background

Published in June 1998, the ESSC-SSB joint study on *US-European Collaboration in Space Science* ([Ref. App.4-1]) examined several past and ongoing missions and assessed the importance of international collaboration for large-scale exploration projects. Various recommendations in this study were presented in the hope that they would serve as guidelines to the scientific communities and space agencies for future cooperative missions.

In NASA the present tendency to favour "better, faster and cheaper" spacecraft for planetary missions, while being well-adapted to certain types of event-oriented missions (e.g. exploration of small bodies in the solar system), can probably not on the other hand deal adequately with major programmes where (i) more than a single mission is required for success and (ii) a very broad community of scientists is concerned (e.g. astronomy, geo-sciences, life sciences, space physics, planetary sciences). These situations are bound to occur in promising areas, e.g. future planetary exploration missions, the search for planets around other stars. Emerging fields such as exobiology, would also benefit from a worldwide cooperative approach.

Supporting this statement is a major finding from an SSB-NRC report on *Assessment of Mission Size Trade-offs for NASA's Earth and Space Science Missions*, published in August 2000 ([Ref. App.4-3]), which states that "... A mixed portfolio of mission sizes is crucial in virtually all Earth and space science disciplines to accomplish the various research objectives...". NASA's recent emphasis on "smaller" planetary missions with the larger ones needed for major objectives indeed follows this finding.

A more recent and growing concern is the evolving implementation of export control regulations on the conduct of international space cooperation (ITAR[1] rules).

ESA on the other hand finds itself in a situation where the so-called "Cornerstone" elements of the Horizons 2000 programme, decided at a time of financial stability, represent a radically different approach to the one followed by NASA. Although a token of European leadership in these specific areas, these large programmes become more difficult to achieve in the light of a continuous financial erosion after the Toulouse 1995 and Brussels 1999 ministerial decisions. This misalignment of strategies between Europe and the USA, added to the very significant budget differences between the two agencies, are major causes for concern in reaching a state of effective cooperation in space science.

In recent years, groups of US, Japanese and European scientists have proposed setting up international Joint Study Teams to reflect on these issues and on possible efficient solutions, and to issue subsequent recommendations and advice to the space agencies. In the area of planetary exploration for instance, a major joint approach ("Sampling the Solar System") would be the equivalent to the Next Generation Space Telescope initiative in the field of astronomy. The importance of such initiatives was recognised by the SSB, the ESSC and the Japanese SRC.

The ESA Director of Science, recognising the difficulties in launching new cooperative missions between, in particular, Europe and the USA, commissioned a study by the ESSC-ESF whose terms of reference are detailed in Appendix 1.

To fulfil this task an *ad hoc* group was formed in June 1999 and has met three times since then. This group decided to organise an international hearing where speakers in the four main areas covered by NASA's and ESA's roadmaps would present their current position, offer assessments of the agencies' roadmaps and propose findings and improved ways of cooperation. To allow this assessment to be carried out with optimal coherence, the *ad hoc* group prepared "matrices" which served to "filter" the roadmaps of the agencies ([Ref. App.4.4-13]). Although termed differently in the languages of both agencies it was decided to refer to the roadmaps in the following way: Astronomy, Fundamental Physics, Planetary Exploration, Heliosphere and Sun (see table p.6). The hearing took place in Nice, France, on 27-28 April 2000; eight "assessors" (speakers) were present, representing these four areas with a balanced US/European coverage. Six "auditors" (three for the SSB and three for the ESSC) then summarised the thematic findings and drafted conclusions and recommendations. Assessors, auditors and *ad hoc* group members are listed in Appendix 2.

[1] International Traffic in Arms Regulation, controlling the transfer of items on the U S munitions list, which covers all spacecraft components and, more broadly, all related technical data.

Roadmap areas	ESA's denomination	NASA's denomination
Astronomy	Origin and Evolution of Stars, Planetary Systems and Terrestrial Planets	Search for Origins
Fundamental Physics	Origin, Evolution and Structure of the Universe – Laws of Fundamental Physics	Structure and Evolution of the Universe (Cosmic Journeys to the Edge of Gravity, Space and Time)
Planetary Exploration	Solar System Exploration	Exploration of the Solar System
Heliosphere and Sun	Exploration of the Sun and Connection Sun/Earth	The Sun-Earth Connection

Table: The assessors examined the missions appearing in the roadmaps of ESA & NASA in the four thematic areas listed above, along with the denominations used by each agency. Some related European national programmes, as well as the recent ESA F2/F3 selections, were also taken into account in the study ([Ref. App.4-14]).

The initial objective was to undertake a joint ESSC-SSB (and possibly Science Council of Japan) study which would establish themes for space science research at a global level. However the SSB has a structure by which any formal activity that leads to the publication of a report or advice to an agency must be carried out within prescribed guidelines for National Research Council project approval, committee member appointment procedures, and report reviews and approvals. On the other hand the SSB can and does provide informal representation at scientific meetings to disseminate the results of SSB studies, to gather information, and to provide input on space and Earth science issues of interest to the SSB and its committees. Such a full-scale and formal study would have carried this exercise beyond reasonable time limits and it was therefore agreed by both parties that the SSB's participation in the international hearing would fall into the second of the above categories of SSB representation.

Although the final product of this exercise is formally an ESSC-ESF study, the SSB actively participated in this process by delegating auditors to the hearing; there is therefore a sense of common ownership of these findings. Prof. Atsuhiro Nishida, Chairman of the Japanese Space Research Committee, was also present as an observer.

It could therefore be possible to use the grounds laid by this report to launch a larger-scale, joint study to investigate possible modalities for carrying out the recommendations extracted in this work. Such a full-scale work might then be undertaken jointly by ESSC, SSB, Japan's SRC and other similar bodies.

The present short report presents the main conclusions of the hearing. The recommended operational structure appears first, followed by the thematic findings in each disciplinary area and by the general findings.

Recommendations

Proposed operational structure

- It is proposed to establish an Inter-Agency Scientific Collaboration Working Group (IA-SCWG), which would include responsible agency executives from, e.g. ESA, NASA, Japan, Russia.

- The aim of this IA-SCWG would be, on a regular basis, to:

  ⇒ provide a global forum for discussing collaboration on large missions (observatories, planetary exploration, data exploitation)

  ⇒ enable coordination of focused science missions (e.g. Explorer, F-type and national missions) within the roadmaps.

- The necessary input to the IA-SCWG would be provided by thematic panels; this would enable a "bottom-up" scientific input.

- In addition to the agency representation, scientific membership in this working group could be decided after consultation and advice from independent scientific advisory bodies, e.g. SSB, ESSC, SRC and others.

- The meeting cycle of the IA-SCWG should be annual.

Thematic findings

Specific findings in the Astronomy area

For Astronomy and Astrophysics, the evolution of the field is driven by increased technical capability thus leading to (i) increased apertures and (ii) increasingly sophisticated instrumentation.

- While the agencies' future plans include a mix of smaller survey and more narrowly focused missions, major advances require the development of large facility-class observatories with global access. A prominent example is the Next Generation Space Telescope (NGST) as the undisputed follow-up mission to the Hubble Space Telescope.

- The roadmaps for such observatories are strikingly similar in Europe and in the USA, in addition to NGST encompassing:

  ⇒ a post-Chandra/XMM-Newton large area X-ray observatory;

  ⇒ infrared interferometry, notably the TPF and IRSI-DARWIN concepts;

  ⇒ ultra-high precision astrometry, i.e. GAIA and FAME.

- This confirms the high priority given by both agencies and communities to each of these fields but also suggests that considerable savings can be achieved through collaboration and in addition, optimum access to observation time could be provided for the large US and European scientific communities.

- For smaller missions coordination and harmonisation is still mandatory to ensure coherence and complementarity *vis-à-vis* the ultimate scientific goals of the roadmaps.

- In Europe, national missions (e.g. Corot from France) can play a similar role in astronomy to that of the Explorers in the NASA programme.

Specific findings in the Fundamental Physics area

For Fundamental Physics several successful international collaborations have been initiated and need to be further pursued.

- LISA provides the clearest example:
  ⇒ The mission concept has been identified by a single science community from both the USA and Europe.
  ⇒ Both ESA and NASA have recognised that the mission is best carried out in cooperation.
  ⇒ The scientific community and the space agencies recognise that a flight test for the technology of LISA is highly desirable; ongoing efforts to exploit a possible ST-3/SMART2 collaboration should be pursued.

- STEP is a US-led mission with a strong European participation both by ESA and by scientific institutes; a mismatch of the ESA and NASA decision procedure is seen as a major difficulty.

- Projects at the border with High Energy Physics e.g. GLAST, AMS, involve collaborations with High Energy Physics agencies (DOE/USA and CERN/Europe). Coordination between these and the space agencies should be pursued to enhance the available resource for this new discipline.

- Other single experiment projects in Fundamental Physics can benefit more from coordination than through direct collaboration. A good example is in the field of high precision clocks were NASA and ESA to fund or study independent projects flown on the ISS.
  ⇒ Two independent cold atom clocks are likely to be operating simultaneously; the possibility of accommodating a superconducting microwave cavity next to these is being actively studied in Europe and in USA.
  ⇒ Coordination of this effort at the scientific level appears essential to fully exploit the scientific potential of such an unprecedentedly high precision clock system.

Specific findings in the Planetary Exploration area

In the field of planetary exploration the Cassini-Huygens mission is an example of a highly successful cooperation.

There is significant redundancy in the current set of planetary missions (e.g. Mercury missions, cometary missions), and many related missions are developed in parallel without the possibility of cross-fertilisation. Planetary science is international and cooperative but also competitive. Science should be the main driver in the selection process of cooperative missions (i.e. a strong bottom-up component). Cooperative missions should thus be part of the roadmaps of the partners, while friendly competition and flexibility should be preserved (need to achieve a balance between the different partners), in the respect of strategic objectives. Cooperation should start in the planning phase.

- Mission types that mandate international cooperation and should therefore be common to both roadmaps are the long duration missions and the large or complex missions (e.g. Cassini–Huygens). In order to avoid duplication of effort and waste of money such large-scale activities should be undertaken in cooperation at the international level. In this context an in-depth (re-)assessment of the present Mars and Mercury exploration strategies should be called for.

- Small-scale missions (i.e. PI-type, fast, and highly integrated missions) as well as technology-driven missions, are being conducted at the institutional level and rather require coordination. Although enabling technologies are the key to a successful mission strategy, purely technological missions may often be of limited scientific value.

- A comparative approach is essential if we are to read the “record of origins”. Therefore coherent programmes (and not media events) are mandatory as more than a single mission is required for success.

- Sample return missions (from Mars, Venus, Mercury, comets, and asteroids) and *in situ* scientific missions (landers, networks, atmospheric probes) are prime candidates for cooperative missions in planetary exploration since they can involve a series of items to be shared (e.g. complementarity between large-scale and small-scale missions, selection of landing sites, communication infrastructure, data and sample management).

- The future exploration of the outer planets will benefit from new scientific concepts but it cannot be undertaken without the development of new technologies (e.g. propulsion systems) that could be shared on a cooperative basis, as successfully achieved for the Cassini-Huygens mission.

- Joint study teams which could involve both scientific and technology people should therefore be set up, possibly under the auspices of existing coordination groups. These joint study teams which could also involve representatives of ESSC, SSB, SRC and other similar national bodies should identify collaborative fields and potential common roadmaps. It must be clearly understood that these joint study teams should not be considered as subsitutes for the already existing agency scientific advisory bodies.

[2] Solar Electric Propulsion

[3] Radioisotope Thermoelectric Generators

Specific findings in the Heliosphere and Sun area

The ISTP continues to be a highly successful programme for Sun, Earth and Heliosphere studies and has demonstrated the essential unity of the field.

- The Sun-Earth system and the Heliosphere must therefore, and now can, be treated as a unified system and provide the prime example of a non-linear, non-local, process on an astrophysical scale.
- There are still major steps to be taken in basic plasma physics by *in situ* space missions. These will be addressed by CLUSTER and some follow-up constellations.
- For the future, space plasma physics will merge into planetary, solar and heliospheric physics and should be recognised as an essential element of such missions. Major future planetary, solar and heliospheric missions should therefore incorporate reasonable complements of *in situ* plasma, particle and field experiments. Such missions, almost inevitably, will be candidates for inter-agency collaborations, but at least must be subject to coordination.
- Constellations (e.g. Storms, Inner Magnetosphere) will be important for magnetospheric response studies – many can be implemented with limited instrumentation by single agencies. However given the complex nature of collisionless plasmas, use of fewer spacecraft with wider complementarity of instrumentation may often be more appropriate.
- Outer heliospheric missions such as the Heliospheric Imager and Sun Sampler might be more efficient if considered as an element of an outer planetary mission, which thus requires larger payloads and, perhaps, longer travel times.
- Space weather activities can be divided into three phases:
  ⇒ research, which is still ongoing, for instance by the Solar Stereo mission. Constellations will be appropriate tools;
  ⇒ development of simple algorithms to extract key parameters which can be used for forecasting;
  ⇒ the operational phase; the latter will have to be carried out by interested agencies.
- Recognition of the importance of basic research for space weather activities will lead to the development of new scientific instrument suites, data modelling efforts and visualisation methods.
- Enabling technologies such as SEP[2], solar sails, spacecraft autonomy, specialist data compression techniques and RTGs[3], are being developed much more aggressively in the USA than in Europe.
- It was recognised with concern that the space plasma community in Europe is severely endangered, in particular in Germany and Sweden. It is important that the challenges and goals for *in situ* plasma research throughout the solar system are recognised and steps are taken to maintain and develop the current expertise.
- Efficient long-term planning plus flexible reaction to new discoveries will require international scientific collaboration and coordination as well as with flexibility on the part of national agencies.

General findings

On the basis of the thematic areas studied during the hearing, general issues common to all fields were identified and are presented below. They served as the basis for the proposal of the operational implementation scheme.

- Agencies and their scientific advisory bodies must (continue to) construct scientific roadmaps, select and prioritise missions.
- Following their definition by the agencies, a rational and systematic approach to the harmonisation of the agencies' scientific roadmaps should be undertaken on a regular basis; an operational implementation scheme is proposed in the section on Recommendations (p.7).
- We encourage the harmonisation of European national space science planning with ESA roadmaps, including data exploitation issues.
- It is important to maintain a friendly scientific competition at the instrument selection level, in respect of the strategic objectives of the other partner(s).
- Current application of ITAR in the USA is having an increasingly detrimental impact on international scientific collaboration and is particularly damaging in the space science area where global collaboration is crucial. It is thus important that the nature of this impact and possible ameliorations be discussed and understood by the space agencies in order to make helpful suggestions to the relevant government bodies.

Appendix 1

Terms of reference of the study

The purpose is to create a truly global endeavour in space science, avoiding overlapping and waste of resources. This can be achieved by making sure that all major space science programmes, i.e., those of NASA, ESA and Japan's SRC are properly coordinated and do not compete irresponsibly but are complementary. Ideally the joint study should therefore define for each theme a roadmap, in which all spacefaring agencies will play a role. In particular the ESSC-ESF should make sure that Europe's space science priorities can be incorporated in roadmaps and/or international programmes such as ISTP, given the present European financial context.

On this basis, the ESSC-ESF should prepare the joint study by:

1. undertaking an overall analysis/review of all major space science programmes and the respective priorities in ESA, NASA, Japan, Russia, etc.;
2. extracting/defining from them main themes or potential international programmes;
3. proposing ways and means to establish international roadmaps in which the different projects foreseen in ESA-NASA, etc, can find their place in a complementary way;
4. reporting on this study at the June 2000 SPC meeting.

The priority areas defined for the ESA science programme by the Horizon 2000 Plus survey committee are:

- a Cornerstone mission to Mercury addressing both planetary and magnetospheric aspects
- participation in the Mars exploration mission
- participation in an international solar mission
- to continue participation in the HST programme and in possible successor programmes
- infrared astronomy: development of detectors and mirrors
- a Cornerstone level programme in interferometry (aiming at astrometric observations at 10 microarcsec level; detection of planets around other stars)
- analysis of a major high-energy astrophysics facility in the context of the space station
- a Cornerstone level programme on the observation of gravitational waves in particular at low frequencies below 1 Hz

For ESA the requested analysis/review involves:

- examining which among the above priority areas can be defined as themes
- establishing for each theme a possible roadmap, with indications of the scientific and technological elements, milestones and optimal schedules
- indicating for each roadmap the elements in which ESA can play a leading role. This will be done in the light of what is known about the space science programmes of other agencies
- identifying an ideal level of involvement for ESA in all elements of each roadmap

It was agreed between ESA Director of Science and ESSC-ESF that the above guidelines represented an ideal outcome of the study which proved difficult to reach in practice. However, the study has resulted in very concrete proposals being made to the ESA Executive.

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Roadmaps

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International Hearing on Collaboration in Space Science

Nice (France), 27-28 April 2000 – Acropolis Congress Centre, Room Galliéni 1

PROGRAMME

Thursday 27 April 2000

09.00 **Introductory Session**
09.00 Welcome address and scope of the hearing from the ESSC Chair *(J.L. Culhane)*
09.15 Discussion

09.30 **Session on Solar System Exploration**
Assessment of NASA and ESA roadmaps in solar system exploration
09.30 European perspective *(E. Grün)*

10.15 – *Break* –

10.45 US perspective *(T. Owen)*

11.30 Discussion on solar system exploration

12.00 **Session on Fundamental Physics**
Assessment of NASA and ESA roadmaps in fundamental physics
12.00 European perspective *(M. Jacob)*

12.45 – *Lunch* –

14.00 **Session on Fundamental Physics** (cont.)
Assessment of NASA and ESA roadmaps in fundamental physics
14.00 US perspective *(N. Bigelow)*
14.45 Discussion on fundamental physics / structure & evolution of Universe

15.15 **Session on Heliosphere and Sun**
Assessment of NASA and ESA roadmaps in heliosphere and Sun
15.15 European perspective *(S. Solanki)*

16.00 – *Break* –

16.30 US perspective *(G. Haerendel)*

17.15 Discussion on heliosphere & Sun / Sun-Earth connection

17.45 Adjourn.

Friday 28 April 2000

09.00 **Session on Astronomy**
Assessment of NASA and ESA roadmaps in astronomy
09.00 European perspective *(J.-L. Puget)*
09.45 US perspective *(J. Grindlay)*

10.30 – *Break* –

11.00 **Session on Astronomy** (cont.)
11.00 Discussion on astronomy / Origins

11.30 **General Session** *(All)*
General discussion on disciplinary roadmaps
Definition of a frame to identify guidelines and findings

12.30 – *Lunch* –

14.00 **Auditors Session** *(Auditors)*
14.00 Findings in astronomy
14.20 Findings in fundamental physics
14.40 Findings in heliosphere and Sun
15.00 Findings in solar system exploration
15.20 General findings

16.00 – *Break* –

16.30 **General Session** (cont.) *(All)*
Assessment of NASA and ESA roadmaps in space science
General discussion
Guidelines for drafting the final report

18.00 Adjourn.